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Through-the-Sensor Determination of AN/AQS-20 Sensor Performance Demonstration 1, December 13 through 17, 2004

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14. ABSTRACT

The first of three FY05 AN/AQS-20 Through-the-Sensor (TTS) Rapid Transition Process (RTP) demonstrations was successfully conducted on December 13 through 17, 2004, in the Mine Warfare Room at NAVOCEANO. The end-to-end demonstration took raw AN/AQS-20 Volume Search Sonar (VSS) and side scan sonar (SSS) data, processed, fused, and delivered them to the Mine Warfare Environmental Decision Aids Library (MEDAL) Tactical Decision Aid (TDA). This demonstration was a representative simulation that showed the connectivity and functionality using previously collected raw AN/AQS-20 Engineering Development Model (EDM) data with other overlapping historical datasets south of Panama City. In this demonstration, the datasets were processed and fused in a laboratory and placed locally in the Geophysical Database Variable Grid Dynamic (GDBV-D) and remotely on a Tactical Environmental Data Services (TEDServices) Gateway. Output formats were successfully ingested into a MEDAL installation using MEDAL's ftp interface. RTP Seafloor Bathymetric and Environmental Data (SeaBED) software worked as designed, data were sent and received in the correct formats, and SeaBED software did not interfere with the normal operation of the Bottom Mapping Workstation (BMW) software. This report summarizes the results of Demonstration 1 of the AN/AQS-20 RTP.

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TTS DETERMINATION OF AN/AQS-20 SENSOR PERFORMANCE DEMONSTRATION 1, DECEMBER 13 THROUGH 17, 2004

1. INTRODUCTION AND BACKGROUND

The first of three FY05 AN/AQS-20 Through-the-Sensor (TTS) Rapid Transition Process (RTP) demonstrations was successfully conducted from December 13 through 17, 2004 in the Mine Warfare (MIW) War Room at the Naval Oceanographic Office (NAVOCEANO). The end-to-end demonstration took raw AN/AQS-20 Volume Search Sonar (VSS) and side scan sonar (SSS) data, and processed, fused, and delivered it to the MIW Environmental Decision Aids Library (MEDAL) tactical decision aid (TDA). This demonstration was a representative simulation that showed the connectivity and functionality using previously collected raw AN/AQS-20 Engineering Development Model (EDM) data with other overlapping historical datasets south of Panama City. In this demonstration, the datasets were processed and fused in a laboratory, and placed locally in the Geophysical Database Variable Grid Dynamic (GDBV-D) and remotely on a Tactical Environmental Data Services (TEDServices) Gateway. Output formats were successfully ingested into a MEDAL installation using MEDAL's ftp interface. RTP Seafloor Bathymetric and Environmental Data (SeaBED) software worked as designed, data were sent and received in the correct formats, and SeaBED software did not interfere with the normal operation of the Bottom Mapping Workstation (BMW) software. This report summarizes the results of Demonstration 1 (DEMO 1) of the AN/AQS-20 RTP.

The Naval Research Laboratory (NRL) is developing techniques that use the data stream from tactical systems to also extract ocean environmental measurements for near-real-time use [1]. The AN/AQS-20 RTP is designed to demonstrate an end-to-end TTS environmental data collection concept of operations using the AN/AQS-20 mine hunting sensor on the HSV-X. The end-to-end concept includes sensor data collection and continues through processing, fusion, distribution, and use in TDAs. Key components of the effort include automating and hardening the environmental data inversion routines, fusion of dynamic in-situ TTS data with historical data in near real-time to refresh the environmental picture, and delivery of the information to TDAs [2].

Under sponsorship by the Oceanographer of the Navy and SPAWAR PMW 180 management, TTS environmental data collection from the AN/AQS-20 was demonstrated [3]. The main technical objectives of the RTP, under ONR, NRL, and CNO N6/7 sponsorship, are to take the program to the next step by developing data fusion techniques and methods for distributing the data [4]. Geophysical data fusion techniques to merge near real-time dynamic data with historical data were used for sediment and bathymetric data to generate a "best" environment. The TEDServices architecture was integrated into the RTP SeaBED software package to demonstrate the end-to-end TTS process from sensor data collection to use in TDAs and reach-back to NAVOCEANO.

2. DEMONSTRATION 1

The demonstration was conducted in a laboratory setting at NAVOCEANO in their MIW War Room from December 13 through 17, 2004. Personnel from NAVOCEANO, SAIC, and NRL participated in

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the demonstration. NAVOCEANO operators ran the BMW Unified Sonar Image Processing System (UNISIPS) and Comprehensive Environmental Assessment System (CEAS) software. SAIC operated the MEDAL workstation. NRL operated the RTP-developed SeaBED software and provided for TEDServices connectivity. During the demonstration, briefs were given to LCDR Steve Martin from OPNAV N752, CAPT Bob Kiser (Commander Naval Meteorology and Oceanography Command [CNMOC] MIW) Business Line Manager, and VIPs from NAVOCEANO and NRL.

2.1 Scenario

A simple operational scenario was chosen for the demonstration that was centered on existing AN/AQS-20 data. The scenario is depicted in Fig. 1 with an objective on land, an assault lane, and an inner transit area. The fictitious task was to determine AN/AQS-20 sensor performance against a potential mine threat in the inner transit area (ITA).

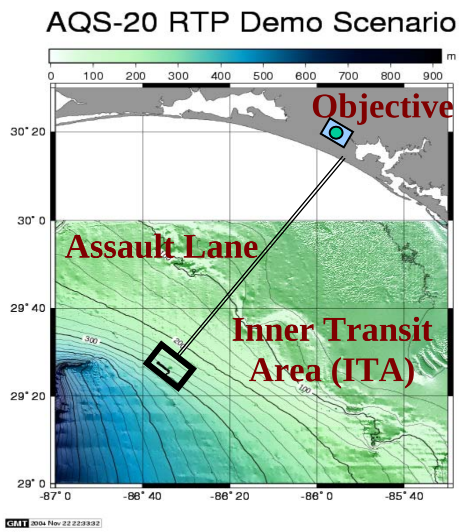

Fig. 1 — Scenario used for RTP DEMO 1

2.2 Data

Data used in DEMO 1 were obtained from existing AN/AQS-20 data sets. No new flights were conducted for this demo. As a result, some of the data components had to be "repositioned" such that the data sets would overlie the same geographic area chosen for the ITA.

The ITA was established where Volume (VOL) mode data were collected during a flight on May 6, 2004. High-resolution high speed recorder (HSR) data and low-resolution mission data were recorded during the flight. The geographic location of this data remained unchanged so that the bottom impedance and bathymetry collected by the AN/AQS-20 and processed by the RTP SeaBED software would match historical data for the data fusion process, an RTP 6.2 development. An AN/AQS-20 sidescan data set, flown in Single Pass Shallow (SPS) mode on November 12, 2004, and recorded as mission data, was repositioned geographically to overlay the ITA area. These data were used to produce the clutter category and roughness information needed to calculate Doctrinal Bottom Type (DBT). The sidescan data were processed though NAVOCEANO's standard UNISIPS software to produce the "fake" clutter category and roughness.

2.2.1 VOL Mode Data

Twenty-four minutes of VOL mode HSR data were recorded on two track lines. The location of the HSR data is shown in area "a" of Fig. 2 and is in a 200-m test field. These data include 1471 pings from the VSS sonar. Water depth in the field ranges from 175 to 190 m. The total volume of data on the HSR was approximately 20 to 30 Gb for this test. The high speed data were recorded on the AN/AQS-20 HSR and copied to a new RAID to simplify classified processing. The new RAID is essentially the same as the HSR.

One hundred and nine minutes of VOL mode Mission Data were recorded. The location of the data is also from area "a" of Fig. 2 relative to NSWC-Panama City. Eleven track lines of mission data were recorded with a total of 6,500 pings. The data were received for analysis on a DVD copy of the Mass Memory Unit (MMU) mission recorder.

2.2.2 SPS Mode Data

Forty-two minutes of sidescan sonar imagery data were collected in area "b" of Fig. 2. The location is very close to shore but provides adequate clutter density and roughness for mine warfare (MIW) DBT calculations. The SPS data were flown in the shallow water test field on November 12, 2004. Water depths in this field are on the order of 15 to 18 m. Approximately 2900 sounding values were recorded on the MMU spanning approximately 48 min. The data were received for analysis on a DVD copy of the MMU mission recorder. A summary of the AN/AQS-20 data used in DEMO 1 is provided in Table 1.

2.2.3 Historical Data

Historical bathymetry and bottom surface sediment type data for the DEMO 1 test were obtained from NAVOCEANO covering the entire Panama City Operating Area (PCOA). Surface sediment data are from the GDBV database and historical bathymetry is from the DBDBV database. NAVOCEANO also provided unclassified MIW environmental data for the Panama City area as MEDAL builds 7 and 9 files. The data types provided are bottom type, bottom category, clutter density, roughness, and HFEVA sediments.

Historical MIW databases required to support MEDAL computations in DEMO 1 were obtained from COMINEWARCOM. These data included previous data from operational exercises in and around the Panama City area. The data consisted of environmental data to support MEDAL worksheet computations like the standard NAVOCEANO products listed above plus classified database products including a mine threat database.

3. END-TO-END DATA FLOW

This section describes the end-to-end data flow from the raw AN/AQS-20 data through processing, fusion, and dissemination to MEDAL and TEDServices. RTP-developed components are described and data examples from DEMO 1 are presented. Descriptions of existing operational components are also described along with examples of how they interact with the new RTP components being demonstrated.

3.1 SeaBED Software

The SeaBED software is an integrated set of modular components for managing AN/AQS-20 data. It is designed to be a component in NAVOCEANO's BMW and is a template for the software architecture that could be used with a host of other TTS systems (BPAUV, REMUS, UQN-4, BQN-17, PUMA). The SeaBED system manages the processing of the raw data through to finished product, storage, and reachback to other users. Functional modules support handling of raw data, display of intermediate results in the processing scheme for quality control, automated editing, fusion of products with historical databases, and reachback capability to other users and productions centers (i.e., NAVOCEANO) via TEDServices. The SeaBED architecture is a centralized system that can be interactively managed using the SeaBED Data Manager (SeaBED DM) application. The connectivity of these systems facilitates data

sharing at the sensor, local, and global levels in near real-time. Figure 3 is a diagram of the primary components.

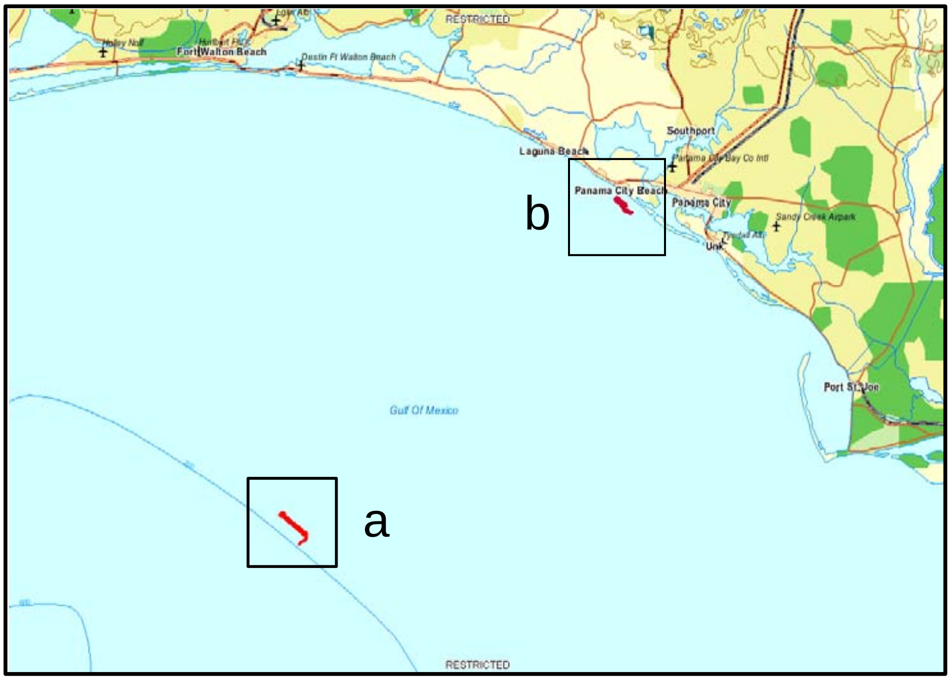

Fig. 2 — Location of (a) VOL data (HSR and Mission data from May 6, 2004), and (b) SPS data (Mission data from November 12, 2004). The (b) data were translated to overlay the VOL mission data.

Table 1 — AN/AQS-20 Data Used in RTP Demonstration 1

AN/AQS-20 Mode recorder used *& data type*	**Date Collected**	**Minutes of Data**	**PCOA Field**	**Number of Pings**	**Number of Soundings or Sediment points**
Volume (VOL) Mode Data	6-May-04		200 m		
High Resolution HSR recorder		24			
Multibeam				1471	38220
Sediment				1471	1471
Mission Data Recorder		109			
Single Beam Bathymetry				6500	6500
Single Pass Shallow (SPS) Mode Data	12-Nov-04		30 m		
Mission Data Recorder		48			
Sidescan Sonar				2900	Imagery

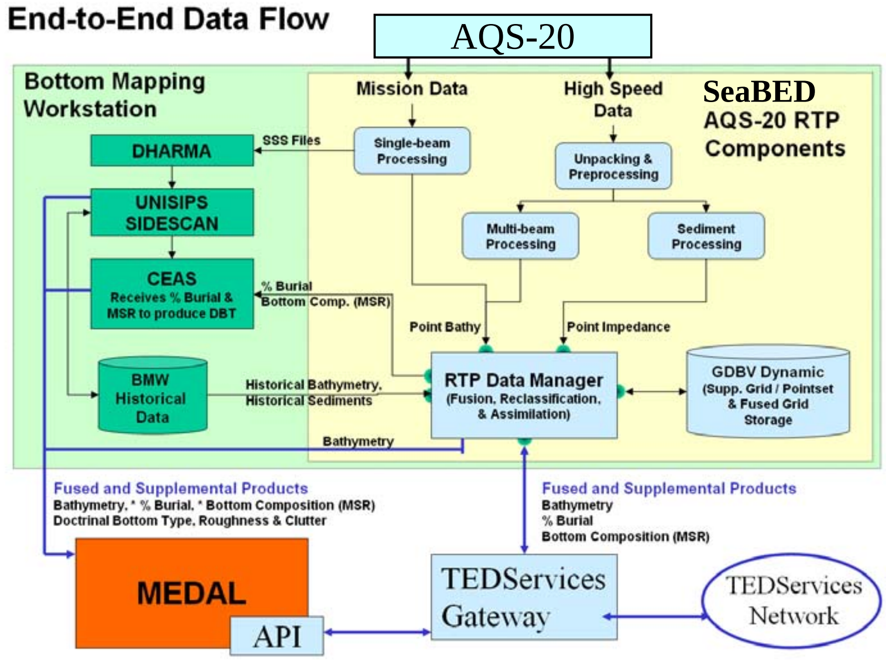

Fig. 3 — SeaBED data processing components and data flow

3.2 Environmental Data Processing

AN/AQS-20 data consist of high-resolution HSR data, and lower resolution MMU mission data. The MMU data contain tow body attitude, positioning, sidescan imagery and other display data depending on the AN/AQS-20 operating mode. The HSR contains the raw time series from the AN/AQS-20 sonars. A special RAID recorder is used to record the HSR data. It is important to note that the HSR data are not recorded on the operational AN/AQS-20 tow bodies; however, OPNAV N752 plans to record the data as a product improvement. In DEMO 1, both types of data were used to generate sidescan imagery, bathymetry, and sediment type information.

3.2.1 Low Resolution MMU Data

MMU data are in a hierarchical file structure and are processed depending on the operating mode for the AN/AQS-20. When in SPS mode, the sidescan imagery are extracted from the MMU data and exported in the appropriate file structure for UNISIPS processing. Single beam bathymetry is also produced from this mode by combining altitude and tow body depth information with the geo-position. When in VOL mode, the display data from the VSS are used to extract the altitude and depth of the tow body to produce single beam bathymetry. However, the display data in VOL mode have a lower resolution than is available through other data types.

3.2.2 High Resolution HSR Data

The raw HSR data requires a preprocessing stage to map the size and location of desirable data on the HSR. In this processing step the data are formatted for the subsequent multibeam bathymetry and sediment type processing steps. HSR data used in DEMO 1 contain only the raw time series data from the AN/AQS-20 sonars. As a result, MMU data are also required to obtain the tow body attitude, timing, and geo-positioning parameters to locate the VSS beam positions on the seafloor.

A second part of the preprocessing for the raw HSR data is deconvolution of the source waveform from the basebanded time series data. This is required prior to the subsequent bathymetry and sediment processing. In this step, the raw time series from each of the beams from the VSS sonar are deconvolved to compress the original transmitted chirp into a single narrow (in time) pulse. The baseband deconvolved time series are passed to the bathymetry and sediment algorithms for further analysis.

3.2.3 Bathymetry

Bathymetry processing is divided into two different processing paths dependent on the type (resolution) of data available. HSR VOL mode data have the highest resolution and best accuracy for multibeam soundings. When HSR VOL mode data are not available, single beam bathymetry can be computed from the MMU data in either SPS or VOL mode as described previously.

When HSR VOL mode data are available, the bathymetry processing uses the deconvolved baseband time series from the preprocessing step. The travel time through the water from the sonar to the bottom is determined from the data using a weighted mean time algorithm for beams that do not exceed 45 degrees from the nadir (downward looking beam). Beams exceeding this limit have grazing angles that are too high for this technique. These data are combined with tow body attitude information, tow body position, water column velocity profile, and tow body depth to determine the water depth and location of each beam on the bottom.

The resulting bathymetry soundings, whether from the MMU or the HSR, are passed back to the SeaBED-DM for further corrections and fusion with historical data.

3.2.3.1 Automatic Bathymetric Filter

After the raw data have been processed, they can be imported into the SeaBED Data Manager for subsequent analysis and manipulation. During the import process, an automatic data filter can be applied to the data to reduce outliers (or erroneous data values). The data filter determines a range in the data that contains all data within three times the standard deviation of the dataset. The range is centered on the mean value of the dataset. The standard deviation filter is applied twice to the dataset, which effectively removes all suspect data values while preserving the majority of the dataset. In the left portion of Fig. 4, a plot of the unfiltered supplemental dataset used in the demonstration is shown from east looking west. In the right portion of Fig. 4, the same dataset is shown after the automatic data filter is applied. In the filtered dataset, all the significant outliers that are prevalent in the unfiltered dataset have been successfully removed. The automatic data filter provides an important capability to trim obvious erroneous data values from a dataset and it produces datasets that are very similar to those produced using the manual data cleaning procedure (area-based editor) used by hydrographers at NAVOCEANO.

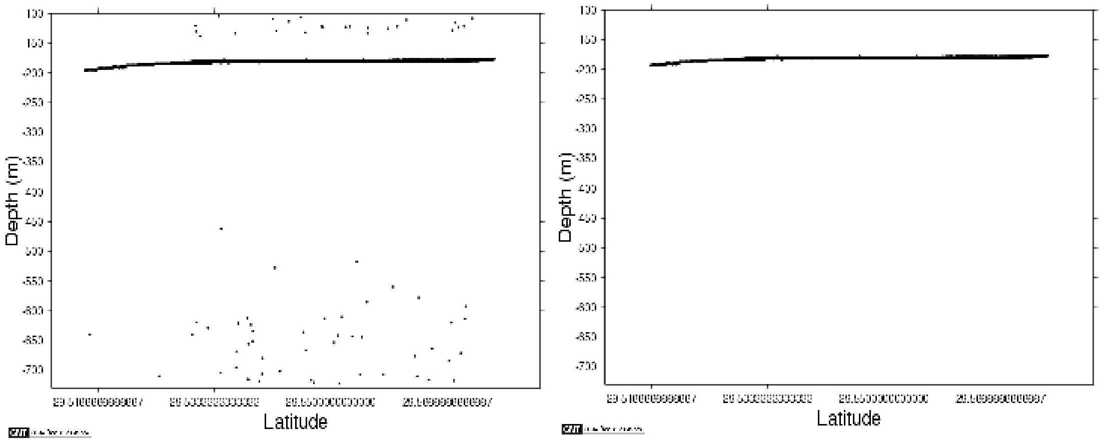

Fig. 4 — Comparison of unfiltered (left) and filtered (right) supplemental soundings

3.2.3.2 Tide Corrections

Tide correction is another optional step that the SeaBED-DM can perform automatically on-scene. The NRL software for tide predictions, PC-TIDES, is run to compute the tidal variations over the area and time that the data were acquired. If desired by the BMW operator, these tide estimates are applied to the data to correct the data to mean sea level. Correction to mean sea level is important for the data to be correctly fused with historical data corrected to mean sea level. This process is optional and operator selectable because the on-scene PC-TIDES algorithms have limited accuracy in some regions of the world and the TEDServices reachback to NAVOCEANO can make this step unnecessary. However, when the reachback to NAVOCEANO is slow or unavailable, the operator has the capability to do the correction in the field.

3.2.4 Sediment

Sediment data are only available using HSR VOL data. The measured quantity is sediment impedance. Sediment processing also uses the deconvolved baseband time series from the preprocessing step. The data manager feeds the time series data into the automated Acoustic Sediment Classification System (ASCS) [5,6,7] software imbedded in the SeaBED Module. ASCS software extracts the impedance characteristics of the seafloor. Empirical relationships are used to convert impedance values to bottom type (mud, sand, and rock) and mine burial potential. These properties are combined with the VSS sonar ping location. The resulting sediment points are passed back to the SeaBED-DM for fusion with historical data.

For the December demonstration, the impedance data produced by the ASCS component of SeaBED was in the form raw point data. Each impedance value was accompanied by a geographical coordinate. The values follow the trackline of the platform as it records information.

3.3 Data Fusion

Two fusion algorithms were tested in DEMO 1. The Oceanic and Atmospheric Master Library (OAML) Feathering algorithm was used primarily for bathymetric datasets and the new 6.2 NRL Fusion algorithms developed for the RTP to work with impedance datasets. However, both algorithms can be applied to either data type. In this section, the primary fusion algorithms are discussed along with demonstration results.

3.3.1 Bathymetry Fusion

The primary fusion algorithm for bathymetry datasets is the OAML Feathering algorithm. The algorithm is a two-dimensional interpolation routine which is implemented in the Generic Mapping Toolkit (GMT) “surface” application [8]. This algorithm was adopted by NAVOCEANO as a standard technique for feathering grids of different resolutions into a single continuous grid [9]. NAVOCEANO also uses this algorithm to produce a grid from irregularly spaced soundings that are collected from a bathymetric survey. In the SeaBED architecture, the OAML Feathering algorithm is driven by user inputs to the SeaBED Data Manager. In addition to having access to the various algorithm performance parameters, the user can select historical and supplemental dataset(s) for inclusion in the fusion process. When the fusion algorithm completes the process, a new fused grid is stored in the local GDBV-D database.

During the demonstration, a supplemental dataset from the AN/AQS-20 was fused with historical data. In Fig. 5, a plot of the supplemental dataset is shown. Figure 6 is historical data from the same area. Finally, Fig. 7 shows the resulting fused grid produced by the OAML Feathering algorithm. The difference between the historical and fused grids is shown in Fig. 8 in a color shaded plot.

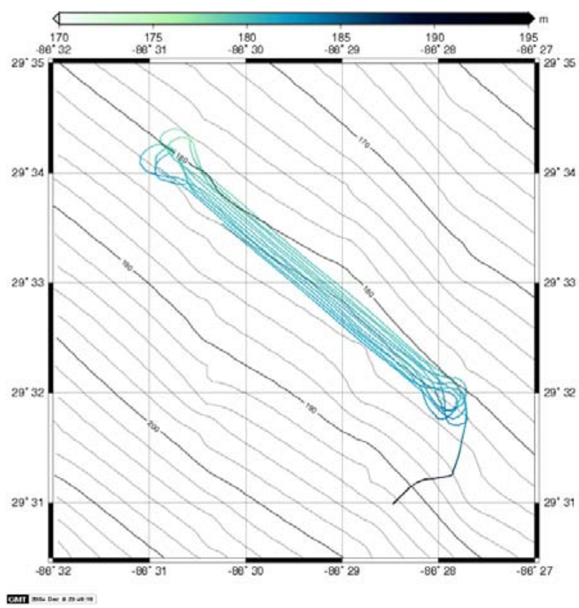

Fig. 5 — Supplemental soundings

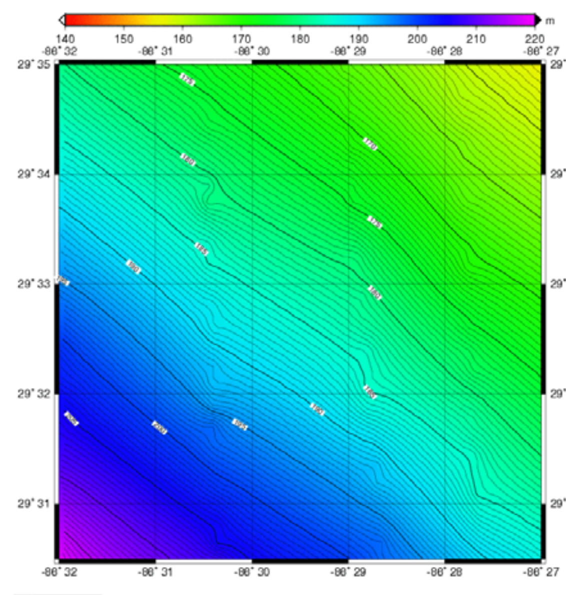

Fig. 6 — Historical bathymetry

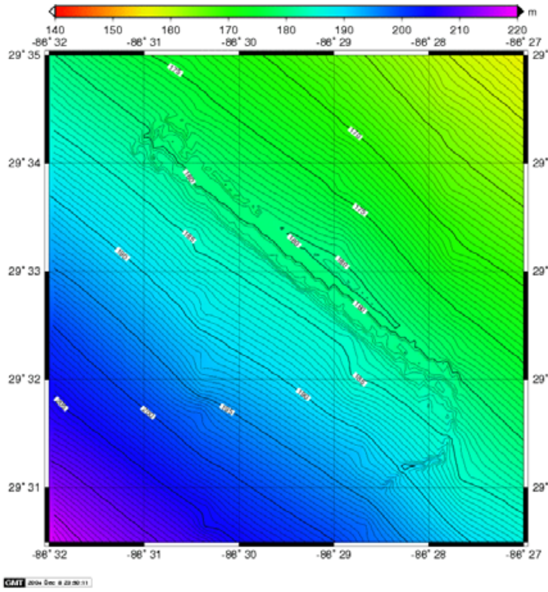

Fig. 7 — Fused bathymetry

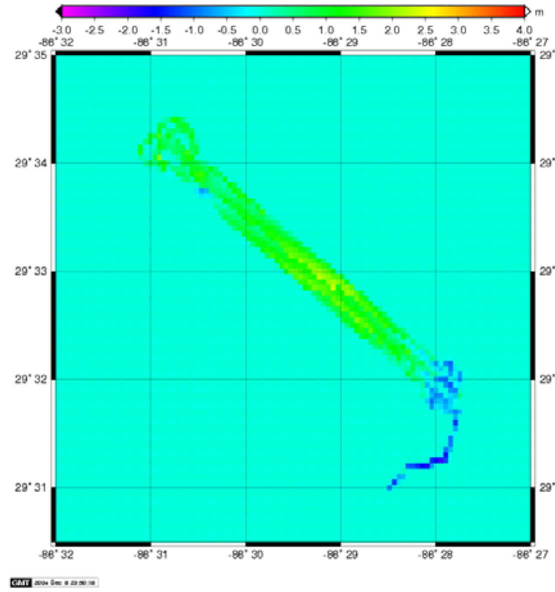

Fig. 8 — Difference plot

3.3.2 Sediment Fusion

Kriging techniques were used to fuse historical impedance data with AN/AQS-20 impedance data. Impedance data acquired along tracklines (or any geospatial measurement of a continuous variable) was fused with historical impedance data with Kriging. Kriging will yield an interpolation that optimizes (minimizes) the variance in the surrounding measurements. However, Kriging requires subjective interpretation of the variances (creating a “best fit” variogram), and is therefore optimal in only a subjective way. More importantly, the resulting Kriging interpolation has associated with it uncertainties such that estimates of the impedance at varying distances away from the trackline can be assigned a finite uncertainty. Areas where the impedance is slowly varying result in high confidence levels of impedance estimates far away from the trackline. Conversely, rapid variation along the trackline degrades confidence in the impedance estimates far away from that trackline. The quantitative spatial uncertainties allow a quantitative merging or fusing of charts acquired with one certainty (e.g., supplemental) to data with a different certainty (e.g., historical). The output of the Kriging algorithm is an evenly spaced impedance grid that contains fused supplemental and historical data. The new impedance grid is converted to burial categories and used in the computation of DBT.

Due to the large differences in variance between the historical data (based on sparse samplings) and the densely sampled supplemental data, the technique greatly favored the supplemental data. To address fusion with the large variances between historical and supplemental data an additional fusion technique will be added for DEMO 2. The new technique will be an added option.

Historical impedance was calculated from the High Frequency Environmental Acoustic (HFEVA) sediment values. Two techniques were examined. The first method took the historical HFEVA value for sediment density and multiplied it by the historical sound velocity for the sediment to derive impedance. These values proved to be too high. The second method tried (and the one used in the DEMO 1) used grain size information from the HFEVA data and a conversion table to derive impedance. These values were closer to reality, within 0.3 impedance units.

In the demo, a supplemental impedance dataset from the AN/AQS-20 was fused with historical data. Figure 9 is a plot of the supplemental dataset. Figure 10 shows historical data from the same area.

Finally, Fig. 11 shows the resulting fused grid produced by the Kriging algorithm. The difference between the historical and fused grids is shown in Fig. 12 in a color shaded plot.

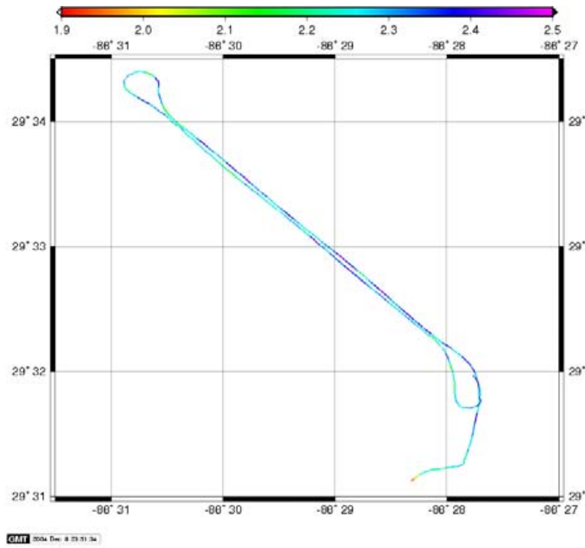

Fig. 9 — Supplemental impedance

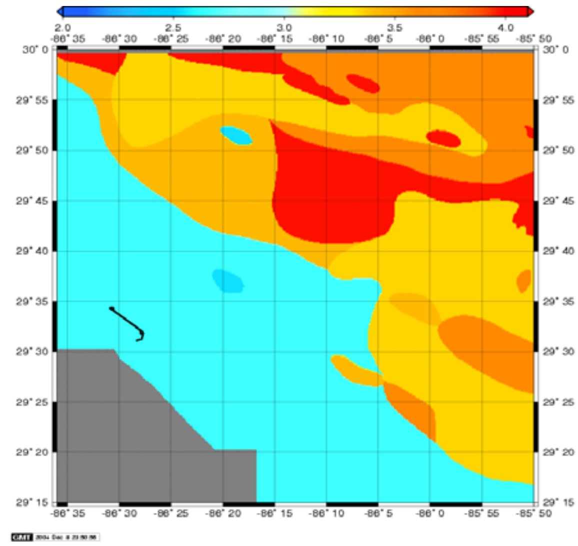

Fig. 10 — Historical impedance

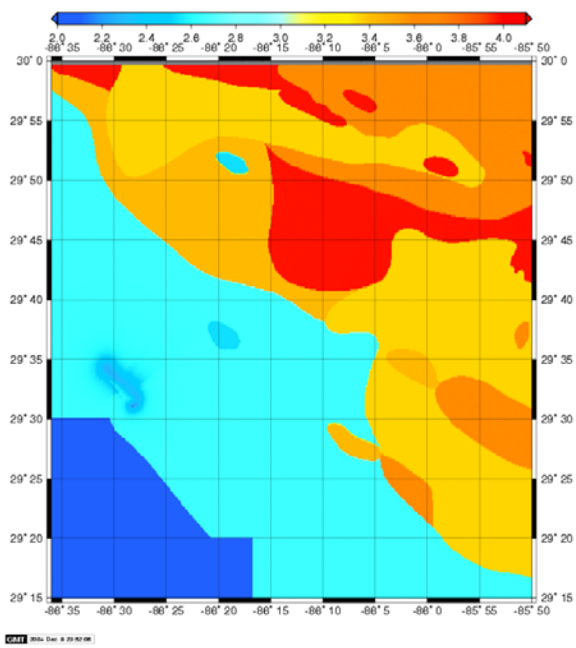

Fig. 11 — Fused impedance

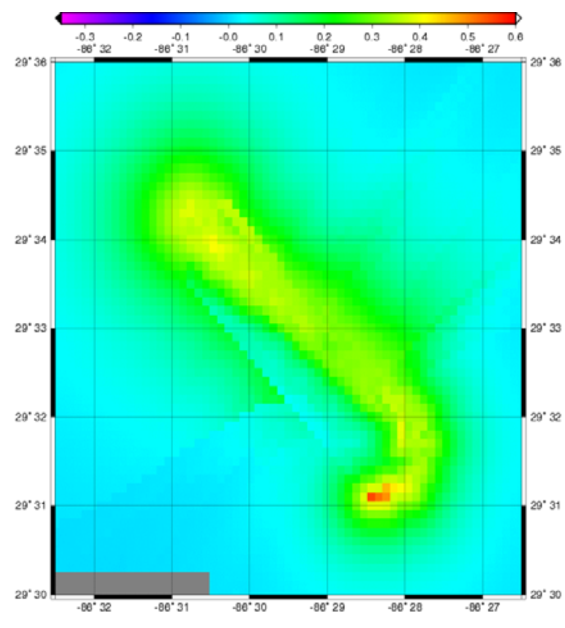

Fig. 12 — Impedance difference

3.4 Data Management

In the early stages of the SeaBED software development, NRL recognized that a central management application was needed to connect and manage processing, fusion, and data storage functions. The SeaBED Data Manager (SeaBED DM), as shown in Fig. 3, provides a Graphical User Interface (GUI) based management interface for interactive control of the SeaBED system. The SeaBED DM allows the

user to process raw data by executing the AN/AQS-20 data processing software directly from intuitive menu systems. Additionally, the SeaBED DM will read historical datasets in the native NAVOCEANO file formats (e.g., MEDAL CHRTR, xyz, etc.) stored on the BMW.

3.4.1 GDBV-D

Geophysical Data Base Variable Resolution – Dynamic (GDBV-D is a key component of the SeaBED Data Manager. GDBV-D is a dynamic database developed to support the SPAWAR-funded GeoAcoustic Inversion Toolkit (GAIT). GDBV-D is a modern, object-oriented database that is implemented entirely in the Java Programming Language [10]. This dynamic database complements the GDBV Historical database that is slated to replace the Oceanographic and Atmospheric Master Library ocean bottom databases in the near future. The GDBV-D is an extensible version of the OAML GDBV that contains generic data objects for storing any type of environmental data. Both the OAML GDBV and the GDBV-D use the same APIs for accessing the datasets stored in a hierarchical data model [11]. In the SeaBED software, GDBV-D fulfills the role of local dataset repository for all supplemental, historical, and fused datasets. Building a local database simplifies the input/output operations in the various SeaBED algorithms since they need only deal with a single database format vise several independent database/file formats.

3.4.2 SeaBED Data Manager

The SeaBED DM provides a tab-based view of the GDBV-D database with individual tabs for supplemental, historical, and fused datasets. Within each tab pane, a tree view of the datasets is shown in which the datasets are grouped by their respective data types. This logical view of the GDBV-D database gives a user the ability to quickly determine the contents of the SeaBED data repository. Moreover, from the SeaBED DM, the user can create, edit, and view associated metadata for each dataset. This metadata is stored along with the dataset in the local GDBV-D and allows the user to record a wide variety of information as string objects.

From the SeaBED DM the user can convert a dataset containing NAVOCEANO's HFEVA32 bottom sediment category codes into impedance values for subsequent fusion with supplemental AN/AQS-20 bottom profile datasets. For example, after a user ingests a historical HFEVA32 dataset, they can convert the datasets into impedance values and then fuse it with a supplemental impedance dataset that was generated from AN/AQS-20 raw data.

Users can also use the visualization capabilities of the SeaBED DM to plot datasets for an expedient quality check. All the supported data types can be viewed in two-dimensions with color-filling using the SeaBED DM. Within the visualization frame (see Fig. 13), the user can modify the color scale and depth range on impedance or bathymetric plots. If a NAVOCEANO bottom-type data type is visualized, the user will see the official color schemes used by NAVOCEANO. A user can also generate an overlay plot in which he or she can display a set of points over a grid. The overlay plot feature is useful for comparing supplemental datasets with historical or fused grids. Using the overlay plot feature, the user can assess the level of agreement between supplemental and historical or the supplemental and fused datasets.

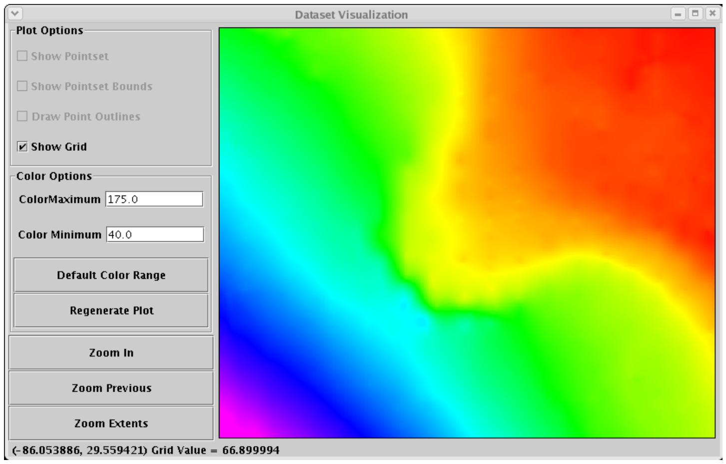

Fig. 13 — Data visualization frame in SeaBED Data Manager

The AN/AQS-20 RTP data fusion algorithms are controlled and executed from within the SeaBED DM. Each data fusion algorithm used in the RTP offers "tweaking" parameters that control optional smoothing techniques and algorithm speed of execution. These parameters can be set through dialog boxes that are customized for each data fusion algorithm.

The SeaBED DM allows the user to export and import data from the supported NAVOCEANO MIW file formats. The formats that are supported for importation into the local GDBV-D are CHRTR (binary grid format), MEDAL CHRTR (binary grid format with special MEDAL header), and xyz (or yxz) ASCII files. The supported export formats are CHRTR, MEDAL CHRTR, xyz (or yxz) ASCII, MEDAL Soundings, GRASS GIS ASCII, and Shapefile.

The SeaBED DM controls all communications between the BMW and the TEDServices Gateways. From the SeaBED DM the user can submit files (any format) to a particular TEDServices Gateway. Also, the user can retrieve data from a TEDServices Gateway Virtual Natural Environment (VNE) as a 3D Grid object. The SeaBED DM also allows the user to create a data order on a TEDServices Gateway, forcing it to execute automatic subscriptions to a particular data type on another TEDServices Gateway. The data order feature is used to receive grids that are placed on the NAVOCEANO TEDServices Gateway automatically.

Although some features of the SeaBED DM are specific to the AN/AQS-20 sensor, NRL has invested a substantial amount of effort into maintaining a generic and flexible interface to the application for possible future expansion to support other TTS systems. Since the application will import point ASCII files and it exports fused grids in standard file formats, it is straightforward to use this application with other TTS systems. Furthermore, the connectivity with TEDServices provides Network Centric Warfare (NCW) capabilities regardless of the source sensor or data type. The SeaBED DM could also be extended to include the functionality of some of the external systems to reduce the number of outside components in the system. By including features such as DBT calculation, the SeaBED DM could play a bigger role in the RTP process and also provide a second look at some of these complex processes for quality assurance concerns.

3.5 Bottom Mapping Workstation

NAVOCEANO supports the MCM mission processing using the BMW (see Fig. 3). The BMW is based on a standard installation of Slackware Linux (currently version 9). The BMW includes NAVOCEANO's UNISIPS software package and is connected via FTP to a PC with the CEAS software package. The SeaBED system was installed on NAVOCEANO's prototype BMW for the December demo. There were no system conflicts or malfunctions of the BMW associated with installing multiple

software systems. The SEABED software ran concurrently with NAVOCEANO's existing software without problem.

3.5.1 UNISIPS Bottom Provincing

UNISIPS is a software suite used for processing raw acoustic imagery from multiple types of SSS to produce digital mosaics, and seafloor characteristics including clutter density and roughness [12]. UNISIPS is able to convert raw acoustic imagery from many SSSs into the UNISIPS format and perform quality checking, bottom provincing, target identification-acquisition, and change detection. In DEMO 1, SeaBED software converted the raw AN/AQS-20 sidescan data from the MMU to UNISIPS format. The UNISIPS software was used to do bottom provincing. In bottom provincing, areas of like bottom roughness are digitized by hand and assigned a roughness category based upon MIW doctrine. This is a manual process that takes several hours. The digitized polygons are written out in ESRI's Shape file format, which can be ingested into other programs, such as the CEAS.

3.5.2 CEAS GIS

CEAS is an ArcInfo based GIS package used for deriving DBT [13]. CEAS was used in the demo to combine the roughness with %burial and clutter information to produce DBTs (A1, B2, etc.). The clutter and roughness are computed by UNISIPS, and %burial comes from SeaBED. Currently CEAS runs only on Windows, while the BMW is a Linux computer. Thus, the files have to be moved from platform to platform manually during the current process. The DBTs are saved in the MEDAL CHRTR format for direct ingest and display in MEDAL.

3.6 TEDServices

Tactical Environmental Data Services (TEDServices) was used to distribute fused and supplemental data from the local GDBV-D to local and remote TDAs via the SeaBED DM (Fig. 3). During numerous FY03 and FY04 exercises, TEDServices, which is the primary Fleet repository and source of meteorological and oceanographic (METOC) data, successfully demonstrated two-way connectivity between data production centers and Fleet units. This new technology provides environmental data via subscriptions and is designed to ensure a common, current environmental view while minimizing bandwidth limitations [14].

3.6.1 Reachback

In the AN/AQS-20 RTP scenario, two TEDServices Gateways are used to demonstrate the reachback capabilities possible with sophisticated remote connectivity. A TEDServices Gateway is installed on the local BMW system and the official NAVOCEANO TEDServices Gateway is used as the domain authority for value-added datasets. From the SeaBED DM, a user can submit raw bathymetry datasets to the official NAVOCEANO TEDServices Gateway in the form of Collaborative Application Sharing Process (CASP) objects. CASP objects are available in the TEDServices API for transferring data files using the TEDServices transport capabilities. Once the CASP object is submitted to the NAVOCEANO Gateway, NAVOCEANO Code N4 (Hydrography) experts can retrieve the objects and write a copy of the raw dataset to their local system for manipulation. The NAVOCEANO personnel will add value to their copy of the dataset by using the area-based editor to remove outlier data points, trim suspect regions of the dataset, add sophisticated tidal corrections, and fuse the dataset with other NAVOCEANO data that have been collected in the survey area. After NAVOCEANO has completed editing and enhancing the dataset, a final grid is produced at an appropriate resolution and then submitted to the NAVOCEANO Gateway. The BMW TEDServices Gateway is configured to use the NAVOCEANO Gateway for all bathymetric data requests through automated subscription services. The BMW Gateway will automatically synchronize itself with the bathymetric datasets located on the NAVOCEANO Gateway. The SeaBED Data Manager will pull data from the local BMW to obtain the NAVOCEANO-blessed grid.

3.7 MEDAL

Mine Warfare Environmental Decision Aid Library (MEDAL), the primary tactical decision aid used in MIW, is the Mine Countermeasures Segment of the Global Command and Control System Maritime (GCCSM). Historical environmental inputs to MEDAL are provided by NAVOCEANO through COMINEWARCOM, and include bottom type, acoustic imagery, bathymetry, weather, SVP, current, sonar correlations checks, and arm thrust measurements [15]. Under N752 sponsorship, NAVOCEANO developed the BMW to provide in-situ environmental data to MEDAL to refresh the environmental picture during dedicated MCM operations. SeaBED software in the BMW adds the ability to update bottom type and bathymetry in-situ along with traditional parameters derived from SSS. Additionally, MEDAL now has an interface with TEDServices with Build 10 currently undergoing Fleet Acceptance Tests.

During DEMO 1, fused sediment information (%burial) was provided to CEAS where it was used to calculate DBT, which was sent to MEDAL. Fused bathymetry was sent to MEDAL from SeaBED (see Fig. 3). MEDAL used the information to calculate Tactically Similar Regions (TSRs, which are derived based on a mine threat, DBT, and bathymetry), number of track lines required against an assumed mine type, and percent clearance (see Fig. 14). MEDAL was able to ingest RTP data without a glitch. Data were provided to MEDAL in its standard formats and used efficiently in calculations.

As lagniappe, SAIC brought a prototype version of MEDAL Build 10 with a TEDServices application programmer interface (API). On December 14, 2004, in a separate area from DEMO 1, MEDAL demonstrated connectivity with TEDServices and its ability to retrieve environmental data, water depth, and sea surface temperature. MEDAL Build 10 will be used in DEMO 2 and will include an RTP-funded upgraded API that can retrieve MCM parameters in addition to standard METOC information.

4. DATA ASSESSMENT AND POTENTIAL IMPACT ON AN/AQS-20 SENSOR PERFORMANCE

Data used for this demonstration were collected off of the coast of Panama City, Florida. The area is the site of numerous exercises, survey operations, and test activities. Consequently, considerable historical data exist and the environment is well understood, and significant differences between historical data and data collected by the sonar were not noted. Generally, the environment is characterized as relatively benign, comprised typically of an A1 DBT.

4.1 Bathymetry Impact

During the demonstration sonar data were processed using UNISIPS, SeaBED, and CEAS. Bathymetry and sediment data were then fused with historical data. Figure 15 shows the National Geophysical Data Center three second bathymetric data for the Panama City, Florida area. Near shore, where the density of the data collected is greater, the contour lines are more defined and complex. Farther offshore, where the density of the data collected is less, the contour lines are smoother. Similarly, Fig. 6 shows that the area surrounding the ITA, the contour lines are smooth, indicating a lower data density. However, the contour lines are more well defined and complex where AN/AQS-20 data were collected in Fig. 7, indicating a higher bathymetry resolution. Additionally, Fig. 8 shows a difference in bathymetry between the historical data and the data collected to be approximately 0.5 to 2 m. The difference does not appear to be significant; this is most likely attributable to the relatively flat bottom characteristics in the region and to the hydrographic and AN/AQS-20A sensor accuracies.

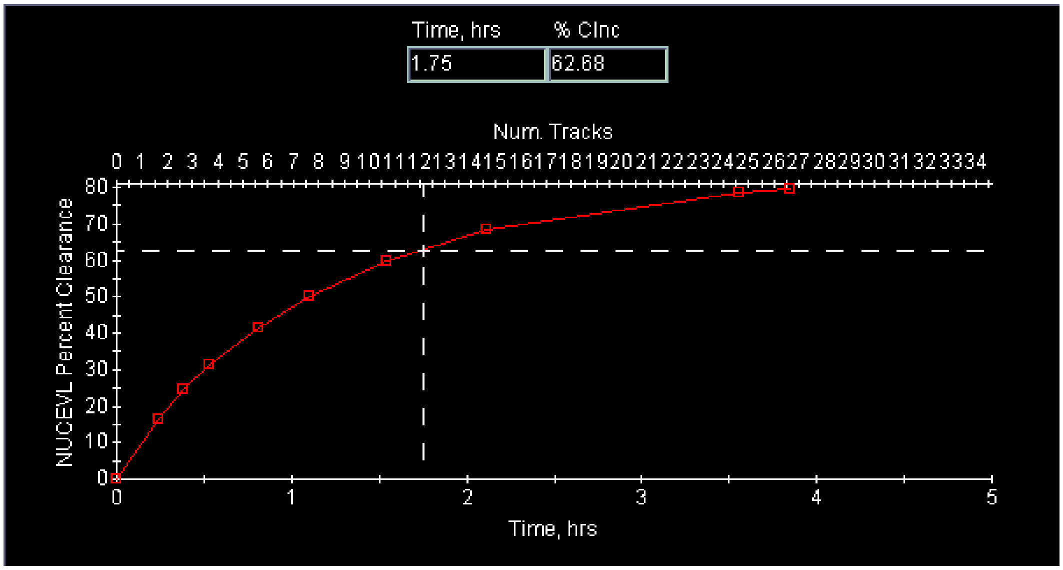

Fig. 14 — Percent clearance computed by MEDAL with DEMO 1 data

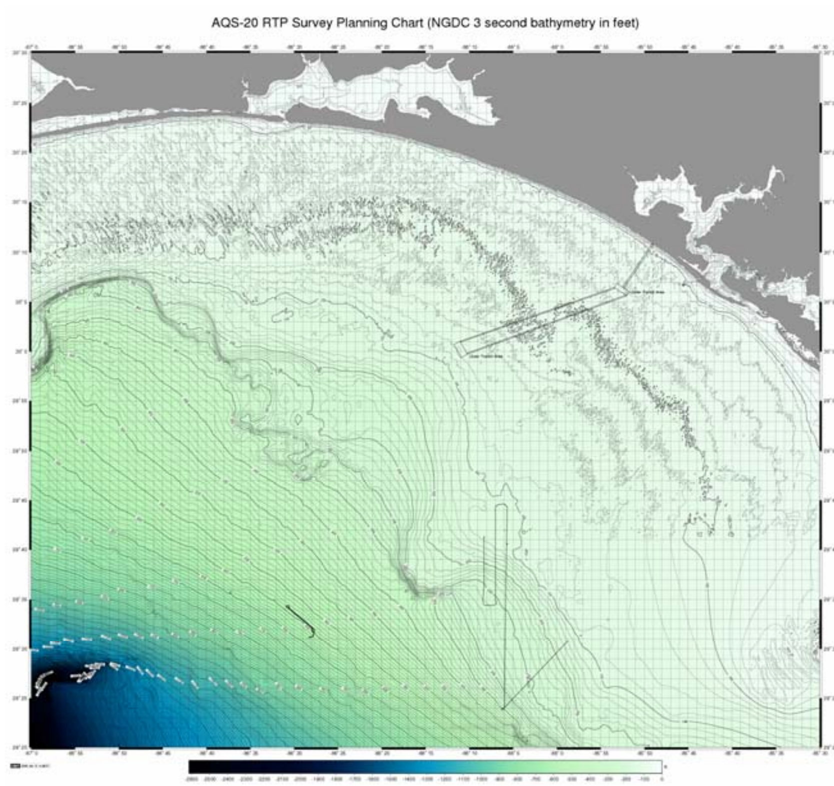

Fig. 15 — NGDC bathymetry for Panama City, Florida. Note the complex contours where high density data exists nearer shore.

4.2 Sediment Impact

Inspection of Fig. 12 indicates an impedance difference of approximately 0.2 to 0.4 between AN/AQS-20 data and historical data. This does not result in a change in doctrinal bottom type, which is attributable to the relatively consistent data in the area. Impedance less than 2.7 indicates mud, from 2.7 to 4.0 indicates sand, and greater than 4.0 indicates rock. The derived historical impedance is in the range surrounding 2.4. Thus, the sediment appears to be composed of a mixture of various grain sizes bordering the mud-sand categories, reflecting a slightly finer grained, more watery sediment than shown in the historical data. However, the difference is minor and does not affect doctrinal bottom type. There is an empirical relationship between impedance and percent burial that has been determined experimentally. From that relationship percent burial, one of the four layers used to determine DBT, is computed. Similar to the bathymetry, a difference between derived historical impedance and NRL fusion impedance is depicted, though the change is not significant.

4.3 Sensor Performance

Extracting sediment data from impedance has three advantages. First, it can be used to validate historical data, thereby assuring that computed timelines and risk are accurate. Second, it can be used to identify areas where historical data are not accurate. Third, it can be used to update the databases at the Naval Oceanographic Office. Data collected and extracted in situ will identify areas where DBTs are more or less favorable for mine hunting. This will either reduce or increase operational timelines and risk, respectively. Figure 14 illustrates the percent clearance computed by MEDAL during the demonstration. Note that due to the limited data available for the demonstration, and given that the data were collected in an area without significant bottom type variation, a detailed analysis of the impact to timelines and risk was precluded. It is anticipated that future demonstrations will provide sufficient data collection to support a more rigorous analysis.

Absent sufficient data collected to illustrate the degree of impact different bottom types can have on operational timelines and risk, Fig. 16 was generated using fictitious data. Bottom type is determined by bottom composition, percent burial, roughness, and clutter. In this analysis clutter and roughness were held constant. Percent burial is a function of sediment type. Only the bottom type was changed from a B (blue) to a C (red). Note that to achieve the same level of clearance, 63 percent, 12 tracks (1.7 hours) were required for a C bottom vs seven tracks (1 hour) for a B bottom, resulting in a 42 percent reduction in timeline and number of tracks. Thus, a significant reduction in timelines and risk can be realized if the actual bottom is determined to be better for mine hunting, and a more accurate assessment of timelines and risk can be realized if the actual bottom is determined to be worse for mine hunting.

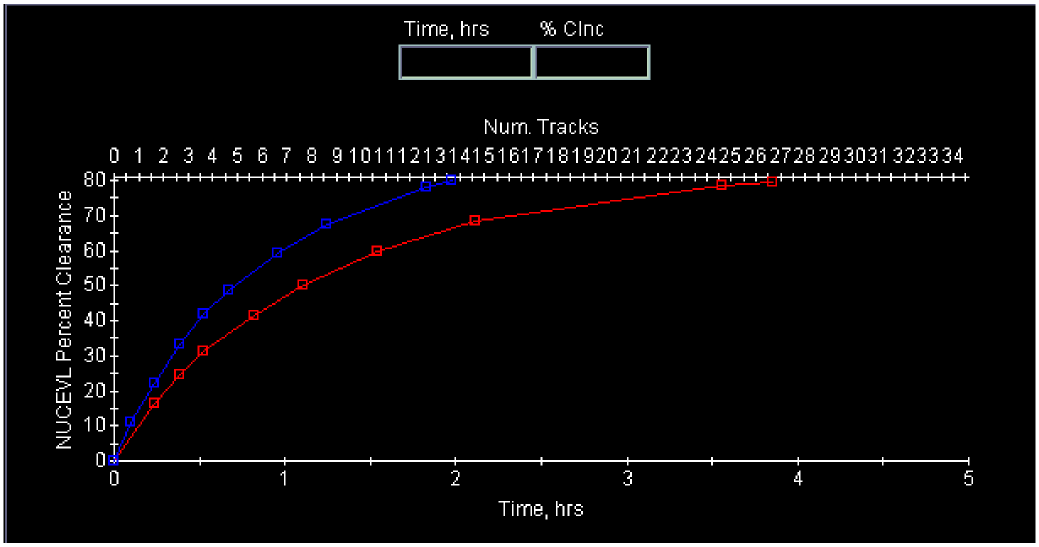

Fig. 16 — Fictitious percent clearance computed by MEDAL showing the clearance times for bottom types B (blue) and C (red)

5. HOT WASH UP

A "hot wash up" meeting was held December 17, 2004, to discuss what worked well and what needed improvement in DEMO 1. Representatives from NAVOCEANO, SAIC, and NRL contributed. This section highlights areas that will be addressed for improvement or change for DEMO 2.

5.1 Sediment Related

HFEVA historical sediment types were converted to impedance with a lookup table using grain size. Historical impedance is needed for fusing with AN/AQS-20 data. A continuous number is needed as the word "sand" can not be fused with the word "mud." The issue is that the 32 HFEVA sediment types are condensed from 200+ extended sediment types in NAVOCEANO's database, and as a result, multiple impedance values are represented in a single HFEVA sediment type, thus introducing inaccuracies. For DEMO 2, NRL will use the 200+ extended sediment types to derive historical impedance, thereby eliminating the issue.

5.2 Bathymetry Related

Some curvature was noted in the AN/AQS-20 multibeam swath information, which implies errors in sound velocity. Sound velocity profiles will be collected for future demonstrations to correct this problem. Secondly, an alternate fusion algorithm developed by NRL (Dr. Todd Holland and Dr. Nathaniel Plant) and used operationally in NAVOCEANO's Warfighting Support Center (WSC) will be added as another data fusion option for both sediment data and bathymetry. Finally, it was noticed that the initial few minutes of AN/AQS-20 VSS multibeam data did not agree with ground truth. Investigation revealed that the data are not accurate when switching the AN/AQS-20 form standby to operational mode. A method for detecting when the system switches to the operational mode will be incorporated into SeaBED for DEMO 2.

5.3 MEDAL Related

MEDAL will upgrade to Build 10 with TEDServices connectivity for DEMO 2. NRL and SAIC will address the hardware, software, and programming issues needed to accomplish this upgrade for DEMO 2.

5.4 TEDServices Related

The NAVOCEANO TEDServices Gateway needs to be upgraded to TEDServices Build 2.12 to handle the RTP data. If this is not possible, the fall back will be to use SPAWAR's gateway at the FLTMCLAB in San Diego. NRL will set up an unclassified gateway to test data flow for the various data types.

5.5 Software Related

The processing speed for HSR VOL data was 6 to 1 as shown in Table 2. Our goal for DEMO 2 is 2 to 1. More automation will be added to SeaBED for DEMO 2 in the normal Operational Mode. The option for doing things in manual will remain. Operator choices for the degree of automation and selection of fusion routines will be performed in a Maintenance Mode (Expert Mode). The CEAS software crashed numerous times during DEMO 1 and required an extra PC. For DEMO 2, NRL will write a stable version of CEAS and imbed it into SeaBED. The option of using the imbedded CEAS or the operational version on a separate PC will be selectable in the Maintenance Mode.

Table 2 — Processing to Collection Time Ratios

SeaBED						
AN/AQS-20 Mode Recorder Used & Data Type	Minutes of Data	Preprocessing & Inversion (minutes)	Processing Time (minutes)	Fusion Time (minutes)	Total Pr & Fu (minutes)	Processing Collection Ratio
Volume (VOL) Mode Data						
High Resolution	24	40	20	90	150	6.25
Mission Data	109		5		5	negligible
Single Pass Shallow (SPS)						
Mission Data Recorder	42					negligible
UNISIPS						
Clutter						1
Roughness			Manual; time varies by operator and data			
CEAS						
Doctrinal Bottom Type			15		15	negligible

5.6 Data Related

In preparation for DEMO 2, an HSR VOL Mode test flight will be conducted in the period of February 28 to March 4, 2005, in an outer transit area south of Panama City, Florida. Two additional flights, one SPS Mode and one HSR VOL mode, for DEMO 2 will be flown March 21 through 25. Ground truth for the demo will be collected by LUMCOM's RV PELICAN in early April following DEMO 2.

5.7 Staging Related

NRL and NAVOCEANO will coordinate with NSWC-PC personnel to address provisions for a classified work area and SIPRNET connectivity for DEMO 2.

6. SUMMARY

DEMO 1 was highly successful. Canned raw AN/AQS-20 data were processed, fused with historical data delivered in the right formats, and used in MEDAL. TEDServices was used to send and receive RTP data in a reach-back mode to NAVOCEANO. SeaBED software was stable, did not interfere with normal BMW processing operations (UNISIPS and CEAS) or affect standard BMW data turnaround times. The

next demo will be more difficult using live data outside of a lab environment. Key challenges that will be addressed prior to DEMO 2 include reducing SeaBED processing times, and more accurate conversion of historical sediment data to impedance using the 200+ enhanced sediment types.

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GLOSSARY

API	Application programmer interface
ASCS	Acoustic Sediment Classification System
BMW	Bottom Mapping Workstation
CASP	Collaborative Application Sharing Process
CEAS	Comprehensive Environmental Assessment System
DBT	Doctrinal bottom type
DEMO 1	Demonstration 1
DEMO 2	Demonstration 2
DM	Data Manager
EDM	Engineering Development Model
GAIT	GeoAcoustic Inversion Toolkit
GCCSM	Global Command and Control System Maritime
GDBV-D	Geophysical Database Variable Grid Dynamic
GMT	Generic Mapping Toolkit
GUI	Graphical user interface
HFEVA	High Frequency Environmental Acoustic
HSR	High speed recorder
ITA	Inner transit area
MEDAL	Mine Warfare Environmental Decision Aids Library
METOC	Meteorological and oceanographic
MIW	Mine warfare
MMU	Mass Memory Unit
NAVOCEANO	Naval Oceanographic Office
NCW	Network Centric Warfare
NRL	Naval Research Laboratory
NSWC-PC	Naval Surface Warfare Center – Panama City, Florida
OAML	Oceanic and Atmospheric Master Library
PCOA	Panama City operating area
RTP	Rapid Transition Process
SeaBED	Seafloor Bathymetric and Environmental Data
SPS	Single Pass Shallow mode
SSS	Side scan sonar
TDA	Tactical Decision Aid
TEDServices	Tactical Environmental Data Services
TSR	Tactically similar region
TTS	Through-the-Sensor

UNISIPS	Unified Sonar Image Processing System
VNE	Virtual Natural Environment
VOL	Volume mode
VSS	Volume Search Sonar
WSC	Warfighting Support Center (NAVOCEANO)